AAPM MEDICAL PHYSICS PRACTICE GUIDELINE # 5: Commissioning and QA of Treatment Planning Dose Calculations: Megavoltage Photon and Electron Beams

- Jennifer Smilowitz (Chair), University of Wisconsin-Madison
- Indra Das, Indiana University School of Medicine
- Vladimir Feygelman, Moffitt Cancer Center
- Benedick Fraass, Cedars-Sinai Medical Center
- Mark Geurts, University of Wisconsin-Madison
- Stephen Kry, MD Anderson
- Ingrid Marshall, Medical University of South Carolina
- Dimitris Mihailidis, Charleston Radiation Therapy Center
- Zoubir Ouhib, Lynne Regional Cancer Center
- Timothy Ritter, University of Michigan
- Michael Snyder, Wayne State University
- Lynne Fairobent, AAPM Staff

University of Wisconsin SCHOOL OF MEDICINE AND PUBLIC HEALTH

AAPM Spring Clinical Meeting, Denver March 2014

Outline: follow outline of MPPG (plus rationale & some implementation experiences)

1. Introduction
   a. Goals
   b. Tolerances and evaluation criteria
   c. Scope/exclusions
2. Staff qualifications
3. Data acquisition
4. Model within TPS software
5. Photon beams: basic dose algorithm validation
   – MatLab code for 1D gamma analysis
   – Trilogy: absolute dose verification, large field/off axis MLC tests
   – TomoTherapy: "tomophants"
6. Photon beams: heterogeneity correction validation
   – Clinac: CIRMS phantom
7. Photon beams: IMRT/VMAT dose validation
   – TomoTherapy – TG 119 tests and clinical case
8. Electron beams
9. Routine QA (downloadable datasets)

What to do/check?

This report only cover dose calculation, the term "commissioning" includes beam data acquisition, modeling, and validation.

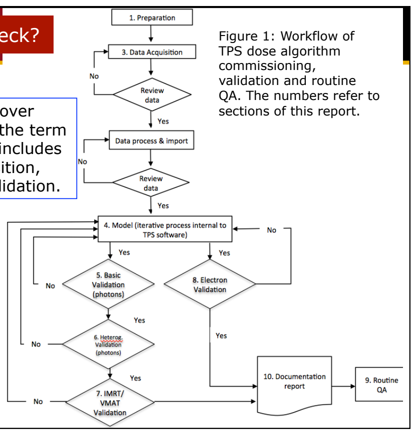


Figure 1: Workflow of TPS dose algorithm commissioning, validation and routine QA. The numbers refer to sections of this report.

Goals

While the implementation of robust and comprehensive QA programs recommended in other AAPM reports is strongly encouraged, the overall objective of this MPPG is to provide an overview of the minimum requirements for TPS dose algorithm commissioning and QA in a clinical setting. Specific goals for this report are to:

- Clearly identify and reference applicable portions of existing AAPM reports and peer-reviewed articles for established commissioning components.
- Provide updated guidelines on technologies that have emerged since the publication of previous reports.
- Provide guidance on validation tests for dose accuracy and constancy (select downloadable datasets/contours & beam parameters are provided for optional use).
- Provide guidance on typical achievable tolerances and evaluation criteria for clinical implementation.
- Provide a checklist for commissioning processes and associated documentation.

Tolerances & Evaluation Criteria (2 "tier approach")

- Wanted to state minimum acceptable tolerance for TPS "basic" dose calculation:
  – "The tolerances for the basic photon tests are widely accepted as minimum criteria for static photon beams under conditions of charged particle equilibrium."
- Wanted to push the limit on some evaluation criteria to find limitations of dose calculations:
  – "Given that there is not widely accepted minimum tolerance for the other verification tests in this MPPG, (including those for VMAT/IMRT), those evaluation criteria must not be interpreted as mandatory or regulatory tolerances. Rather, they are values defined as points for further investigation, possible improvement, and resolution."
- Did not want to state or use any minimum tolerance values not widely accepted/published:
  – "All the tolerances and criteria in this report are based on a combination of published guidelines, the dosimetric audits performed by the Radiological Physics Center, and the experience of authors. Users are encouraged to not only meet these tolerances, but also strive to achieve dosimetric agreement comparable to that reported in the literature for their particular algorithm."

Scope/exclusions

- Title: Commissioning and QA of Treatment Planning Dose Calculations: Megavoltage Photon and Electron Beams
- The scope of this report is limited to the commissioning and QA of the beam modeling and calculation portion of a TPS where:
  – External photon and electron treatment beams are delivered at typical SSDs using a gantry mounted radiation source including conventional and small fields used in IMRT, VMAT, helical tomotherapy delivery, *and SRS/SBRT (still up for discussion).*
  – Modern dose algorithms are utilized including corrections for tissue heterogeneity.
  – *The Multi-Leaf Collimator (MLC) is used as the primary method of shaping the beam aperture for treatments. (individually fabricated IMRT modifiers, cones… still up for discussion)*
- Excludes: (not an exhaustive list, and not all written in document)
  – Non-dosimetric components of system, e.g.: DVH, leaf sequences, contours, image registration…
  – Brachytherapy
  – Proton therapy
  – Non-commercial planning systems
  – Radiation delivered by robots

Outline: follow outline of MPPG
(plus rationale & some implementation experiences)

1. Introduction
   a. Goals
   b. Tolerances and evaluation criteria
   c. Scope/exclusions
2. Staff qualifications
3. Data acquisition
4. Model within TPS software
5. Photon beams: basic dose algorithm validation
   – MatLab code for 1D gamma analysis
   – Trilogy: absolute dose verification, large field/off axis MLC tests
   – TomoTherapy: "tomophants"
6. Photon beams: heterogeneity correction validation
   – Clinac: CIRMS phantom
7. Photon beams: IMRT/VMAT dose validation
   – TomoTherapy – TG 119 tests and clinical case
8. Electron beams
9. Routine QA (downloadable datasets)

Data Acquisition Question

What data do you use when commissioning a new dose algorithm?

1. Collect data according to vendors guidelines
2. Collect some of the vendor recommended data but not all
3. Collect all required data and more
4. Use golden beam data
5. Hey, I thought this wasn't a SAM session.

Staff, Data, Model…

- Staff qualifications – QMP, defer to supervision MPPG
- Data acquisition – defer to TPS manuals for all required data (water tank, and in air for MC) & refer to TG 106. An equipment list/ summary on small field/MLC data acquisition is included:
  – PDD and OF with a small volume detector down to at least 2x2 cm^2
  – MLC intra and inter-leaf transmission and leaf gap:
    - Large chamber if an average intra- and inter-leaf value is specified.
    - Separate measurements, use small chamber under the leaf and film for inter-leaf leakage measurements
  – Measure leaf-end penumbra with a small detector (such as a diode or micro-chamber) to avoid volume-averaging effects
  – Leaf timing for binary MLC systems should be verified using film or exit detector measurements
- Model – refer to manual, iterate as needed using results from validation testing

Outline: follow outline of MPPG
(plus rationale & some implementation experiences)

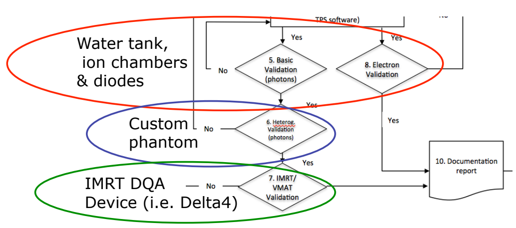
1. Introduction
   a. Goals
   b. Tolerances and evaluation criteria
   c. Scope/exclusions
2. Staff qualifications
3. Data acquisition
4. Model within TPS software
5. Photon beams: basic dose algorithm **validation**
   – MatLab code for 1D gamma analysis
   – Trilogy: absolute dose verification, large field/off axis MLC tests
   – TomoTherapy: "tomophants"
6. Photon beams: heterogeneity correction **validation**
   – Clinac: CIRMS phantom
7. Photon beams: IMRT/VMAT dose **validation**
   – TomoTherapy – TG 119 tests and clinical case
8. Electron beam **validation**
9. Routine QA (downloadable datasets)

Validation Question

What type of <u>dose algorithm validation</u> do you do as part of the commissioning process?

1. None
2. Routine patient specific DQA serves as validation
3. In-house test suite (chamber, array, films etc…)
4. Peer review audit (colleague or RPC)
5. Combination of 3 and 4

Validation Measurements



- Report was written such that user has freedom to use any suitable/available combination of phantoms and detectors.
- Combination of in-house and external audits
- It is recommended to take data at time of commissioning.
- This diagram shows a common set of tools (and what we are using at UW.)

5. Basic Validation: Photon beams

Section 5 (Photons in homogeneous media) has 2 sets of tests:

- 5.1-5.3: "sanity check" of commission data → physics module → planning module and TG 51 calibration value
- 5.4-5.9: test fields that were not used in commissioning. Compare measured and calculated dose distribution.
- Tests should be run for each unique configured beam (energy and wedge)

Photon beams: TPS model comparison (5.1-5.3)

Table 3: TPS model comparison tests and minimum tolerances*

Test	Comparison	Description	Tolerance
5.1	Dose distributions in planning module vs. modeling (physics) module	Comparison of dose distribution for large (>30x30) field.	Identical
5.2	Dose in test plan vs. clinical calibration condition*	Reference calibration condition check	0.5%
5.3	Dose distribution calculated in planning system vs. commissioning data	PDD and off axis factors for a large and a small field size	2%

* No additional measurements required for these tests
** Calibration condition of TPS, not the necessarily of linac per TG 51

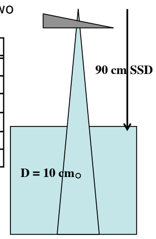
No additional measurements beyond commissioning data needed for these tests.

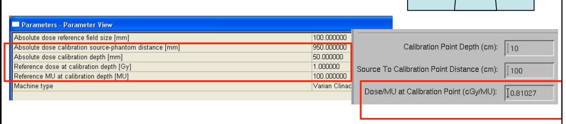
Implementation: 5.Dose in test plan vs. TPS calibration (0.5% tolerance)

- Part of an exercise to confirm "match" between two Varian 2100s

10 MV beams	Meas.(Gy)	TPS calc (Gy)	% diff
Open, 90 cm SSD	0.893	0.891	-0.18
15° W, 90 cm SSD	0.669	0.669	-0.01
30° W, 90 cm SSD	0.543	0.544	0.21
45° W, 90 cm SSD	0.470	0.473	0.71
60° W, 90 cm SSD	0.392	0.394	0.42
Open 100 cm SSD	0.744	0.741	-0.34

10 MV open and wedge absolute dose comparison, 10x10 cm^2 and d=10 cm. The 10 MV 45° wedge exceeded the 0.5% tolerance suggested in the MPPG and is being investigated





Photon beams: Basic tests (5.4-5.)

Test	Description	Sample tests from literature [7]
5.4	Small MLC shaped field (non SRS)	Photon Test 1
5.5	Large MLC shaped field with extensive blocking (e.g.: mantle)	Photon Test 3
5.6	Off-axis MLC shaped field, with maximum allowed leaf over travel.	Photon Test 2
5.7	Asymmetric MLC shaped field at minimal anticipated SSD	Photon Test 6
5.8	MLC shaped field at oblique incidence (30°)	Photon Test 10
5.9	Large (>15cm) MLC field for each a non-physical wedge angle**	--

*Measure: high dose, penumbra, and low dose tail regions at various depths
**Tests 5.4-5.8 are intended for each open and (hard) wedged field. Non-physical wedges are considered an extension of the corresponding open field in terms of spectra and only require the addition of Test 5.9

[7] International Atomic Energy Agency, "Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer," Vienna, 2004.

Accuracy question

How accurate is your worst off axis relative dose calculation?

1. 1%
2. 2%
3. 3%
4. 4%
5. 5%

Accuracy question 2

How accurate is your worst off axis relative dose calculation with a wedge in place?

1. 1%
2. 2%
3. 3%
4. 4%
5. 5%

Section 5: Basic photon tolerances

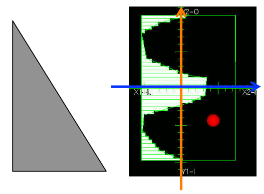
Table 5. Basic TPS photon beam evaluation methods and tolerances

Region	Evaluation Method	Tolerance* (consistent with RPC)
High dose	Relative dose with one parameter change from reference conditions	2%
	Relative dose with multiple parameter changes **	5%
Penumbra	Distance to agreement	3 mm
Low dose tail	Up to 5 cm from field edge	3% of maximum field dose

* Tolerances are relative to local dose unless otherwise noted.
**e.g.: off axis with physical wedge.

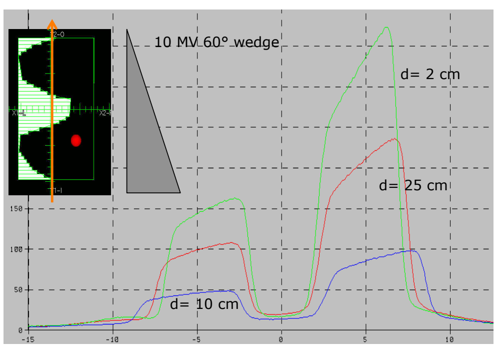
Implementation: 5.5 Large MLC shaped field with extensive blocking (γ analysis)

- Example of a test pattern – that tests many things at once: Off axis PDD (•), 3 cross profiles (2 cm, 10 cm , 20 cm) and 1 in line profile (10 cm) for open and wedge fields



60° wedge, "toe in"

Implementation: 5.5 Large MLC shaped field with extensive blocking (γ analysis)



1D Gamma analysis– open source MatLab code

- Save scan data in Excel and output dicom dose files from TPS (note dose grid origin and resolution).
- Script/detailed users manual will be available on the UW Open Source Medical Devices website and code revision history at github:
  - http://discovery.wisc.edu/home/town-center/programs--events/recurring-conferences/open-source-medical-devices/
  - https://github.com/bredfeldt/MPPG
- Code interpolates data, shifts for best agreement and does gamma analysis according to Low et al, Med. Phys 25(5), 1988

$$\gamma(\mathbf{r}_m) = \min\{\Gamma(\mathbf{r}_m, \mathbf{r}_c)\}\forall\{\mathbf{r}_c\},$$

where

$$\Gamma(\mathbf{r}_m, \mathbf{r}_c) = \sqrt{\frac{r^2(\mathbf{r}_m, \mathbf{r}_c)}{\Delta d_M^2} + \frac{\delta^2(\mathbf{r}_m, \mathbf{r}_c)}{\Delta D_M^2}},$$

$$r(\mathbf{r}_m, \mathbf{r}_c) = |\mathbf{r}_c - \mathbf{r}_m|.$$

Validate gamma calculation with 3%/3mm threshold

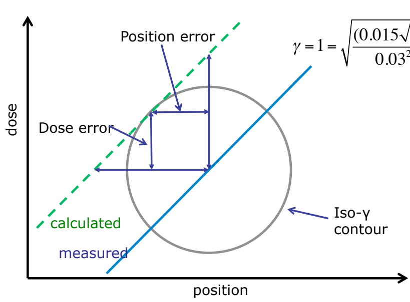
- Create simulated dose profiles A and B
  - A = dose ramp with slope = 0.03 Gy/3mm
  - B = A + 0.03*sqrt(2)
- Input A and B into gamma calculation
- Verify that gamma = 1 at all positions

Thanks to MatLab Master Jeremy Bredtfeldt!

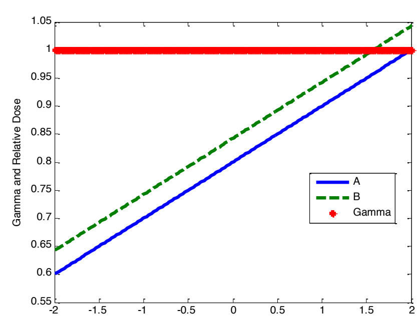
Gamma Calculation Test Case

Min. γ will occur with a dose error is 0.015 √(2) and position error is 1.5 √(2

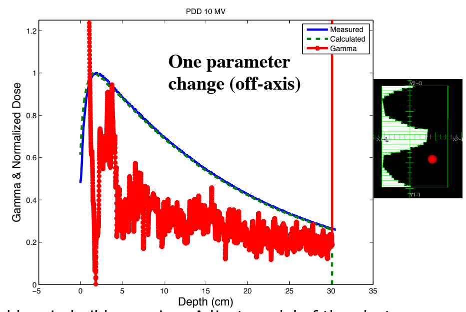
$$\gamma = 1 = \sqrt{\frac{(0.015\sqrt{2})^2}{0.03^2} + \frac{(1.5\sqrt{2})^2}{3^2}}$$



Gamma Calculation Test Results

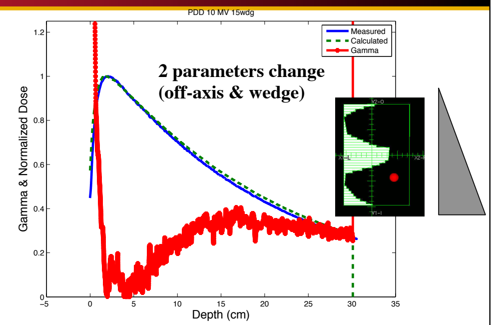


Results from off axis PDD for open 10MV field 2%/0.001mm



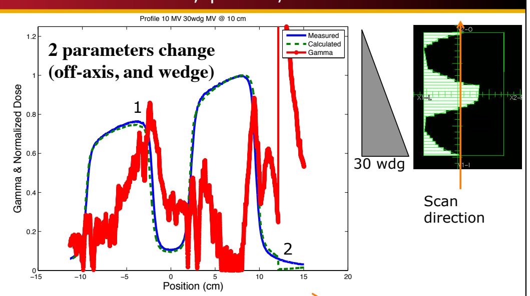
Problem in buildup region. Adjust model of the electron contamination?

Results from off axis PDD for 15 wedge 10MV field 5%/0.001mm



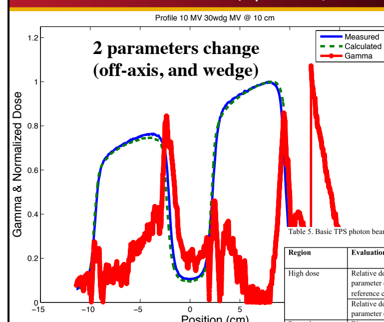
Problem in buildup region. Adjust model of the electron contamination?

Results from d=10 cm inline profile for 30° wedged 10MV field, γ = 3%/3mm



1. 1.Problem in leaf penumbra (T&G) region. Adjust leaf intra or inter leaf leakage model?
2. Problem with jaw closing to MLC defined edge?

Results from d=10 cm inline profile for 30° wedged 10MV field, γ = 5%/3mm



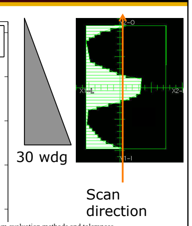
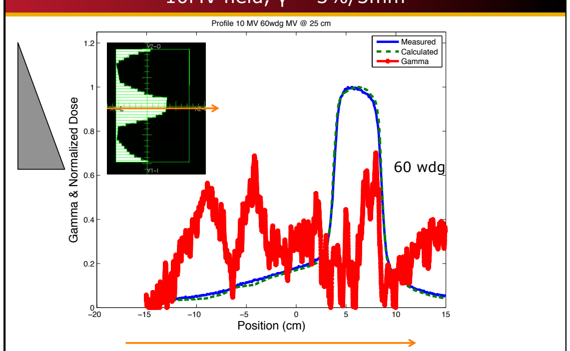


Table 5. Basic TPS photon beam evaluation methods and tolerances

Region	Evaluation Method	Tolerance* (consistent with RPC)
High dose	Relative dose with one parameter change from reference conditions	2%
	Relative dose with multiple parameter changes **	5%
Penumbra	Distance to agreement	3 mm
Low dose tail	Up to 5 cm from field edge	3% of maximum field dose

* Tolerances are relative to local dose unless otherwise noted.
**e.g.: off axis with physical wedge.

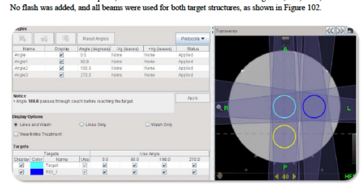
Results from d=25 cm crosline profile for 60° wedged 10MV field, γ = 3%/3mm

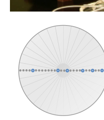


Implementation: Basic test on TomoTherapy

- Forward planned fields are not easily generated in tomo
- "TomoPhants": set of standard plans with different jaw sizes (fixed and dynamic) run on "cheese phantom" with ion chambers for inline profiles (and Delta4 for volumetric DQA.) They are a good alternative to implementation of section 5 tests
- Calculated dose profiles are extracted by Accuray and measured data is analyzed with excel sheets

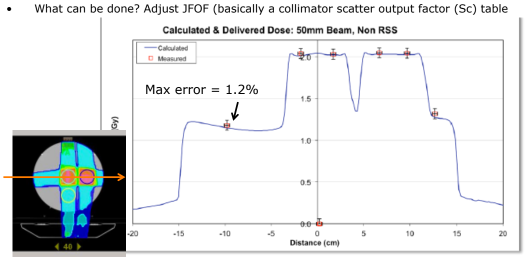
For the *TomoDirectPhant* plans, four beams were added at each cardinal angle: 0°, 90°, 180°, and 270°. No flash was added, and all beams were used for both target structures, as shown in Figure 102.





Implementation: TomoPhant results

- Same plan with helical and tomodirect, for each field size. Results:
  - TomoDirect measured hotter than planned (compared to helical plans)
  - 5 cm FW plans were always hotter than planned (compared to other FW)
  - A1SL Ion chamber, error bars are 3%
- What can be done? Adjust JFOF (basically a collimator scatter output factor (Sc) table



Heterogeneity questions

Which algorithm is not acceptable for dose calculation for lung?

1. Pencil beam
2. Monte Carlo
3. Convolution superposition
4. Discreet ordinance (grid based Boltzman solver)
5. All are acceptable

Section 6: Heterogeneity

Table 6: Heterogeneous TPS photon beam validation tests.

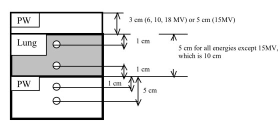
Test	Objective	Description	Tolerances*	Reference
6.1	Validate planning system reported electron (or mass) densities against known values.	CT-density calibration for air, lung, water, dense bone, and possibly additional tissue types.	--	TG 65 [23]; IAEA TRS-430 [7]
6.2	Heterogeneity correction distal ~~and proximal~~ to lung tissue	5x5 cm2, measure dose ratio above and below heterogeneity outside of the buildup region	3%	Carrasco et al. [52]

* Tolerances are relative to local dose unless otherwise noted.

- Modern algorithms (C/S. MC, GBBS, no PB)
- Only test beyond heterogeneity (not in or at boundaries, areas at which it is difficult to measure)
- Only low density tissue

Implementation : Heterogeneity tests (3% tolerance)

- Follow the methodology of the AAPM TG65[4].
- A CIRS 20x20x20 cm^3 Cube Plastic Water phantom ("Cube Phantom") with low density wood (0.27 g/cm^3) inserts.



Phys. Depth (cm)	FS, cm	Pinnacle vs. Measured Dose: No Lung	Pinnacle vs. Measured Dose: W/Lung	CF(Meas.)	CF (Pin.)	CF P-M
4	10x10	-1.9%	-0.8%	0.993	1.003	**1.1%**
7.3		-2.3%	-2.1%	1.067	1.069	**0.2%**
9.3		-2.1%	-2.2%	1.112	1.111	**-0.1%**
13.3		-2.3%	-1.9%	1.140	1.144	**0.4%**
4	5x5	-1.3%	0.3%	0.987	1.004	**1.6%**
7.3		-1.7%	-1.3%	1.055	1.058	**0.3%**
9.3		-1.6%	-1.7%	1.138	1.136	**-0.2%**
13.3		-2.0%	-1.8%	1.172	1.174	**0.2%**

Images from Vladimir Feygelman

Section 7: IMRT/VMAT Verification

Test	Objective	Description (example)	Detector
7.1	Verify small field PDD	≥ 2x2 cm^2 MLC shaped field, with PDD acquired at a clinically relevant SSD.	Diode or plastic scintillator
7.2	Verify output for small MLC-defined fields	Use small square and rectangular MLC-defined segments, measuring output at a clinically relevant depth for each*	Diode, plastic scintillator, mini-chamber or micro-ion chamber
7.3	TG-119 tests	Plan, measure, and compare planning and QA results to the TG119 report for both the Head and Neck and C-shape cases.	--
7.4	Clinical tests	Choose at least 2 relevant clinical cases. Plan, measure, and perform an in-depth analysis of the results.	Ion chamber, film and/or array
7.5	External review	Simulate, plan, and treat an anthropomorphic phantom with embedded dosimeters.	Various options exist.**

IMRT DQA Question 1

What gamma criteria do you use for patient specific delivery QA (DQA)?

1. 1%/1mm
2. 2%/2mm
3. 3%/3mm
4. 4%/4mm
5. I don't do patient specific DQA and/or I don't use gamma criteria for DQA analysis.

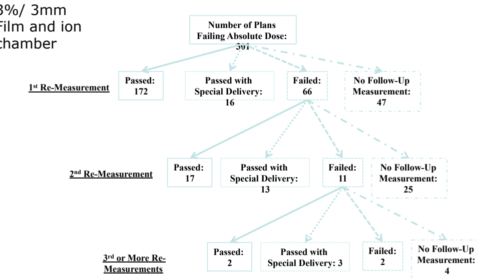
IMRT DQA Question 2

What do you do when a case 'fails' that criteria?

1. increase tolerance by 1%/1mm
2. Re-measure
3. Re-plan
4. Pick tolerance so >95% pass and report tolerance values
5. My plans never fail

MD Anderson Experience with failed DQA's

3%/ 3mm
Film and ion chamber



- Only 3/301 failed cases were re-planned!
- Extreme majority treated as is…

Thanks Stephen Kry

IMRT/VMAT Validation Tests (section 7)

Table 7: VMAT/IMRT Test Summary.

Test	Objective	Description (example)	Detector	Ref
7.1	Verify small field PDD	≥ 2x2 cm^2 MLC shaped field, with PDD acquired at a clinically relevant SSD.	Diode or plastic scintillator	TG-155 (to be published in MP)
7.2	Verify output for small MLC-defined fields	Use small square and rectangular MLC-defined segments, measuring output at a clinically relevant depth for each*	Diode, plastic scintillator, mini-chamber or micro-ion chamber	Cadman et al. [53]
7.3	TG-119 tests	Plan, measure, and compare planning and QA results to the TG119 report for both the Head and Neck and C-shape cases.	--	TG-119 [31]
7.4	Clinical tests	Choose at least 2 relevant clinical cases. Plan, measure, and perform an in-depth analysis of the results.	Ion chamber, film and/or array	Nelms et al. [54]
7.5	External review	Simulate, plan, and treat an anthropomorphic phantom with em	Various options exist.**	Kry et al. [32]

C-shape plan, on tomo

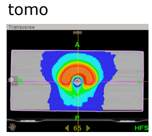
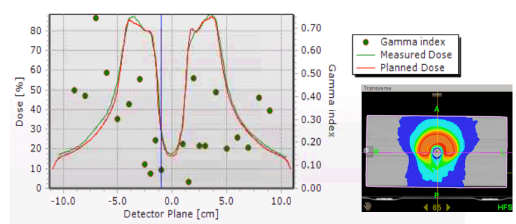


Table 8: VMAT/IMRT Evaluation Methods and Tolerances

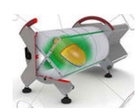
Measurement Method	Region	Tolerance
Ion Chamber	Low gradient target region	2% of prescribed dose
	OAR region	3% of prescribed dose
Planar/Volumetric Array	All regions	2%/2mm*, no pass rate tolerance, but areas that do not pass need to be investigated
End-to-End	Low gradient target region	5% of prescribed dose

*Application of a 2%/2 mm gamma criterion can result in the discovery of easily correctable problems with IMRT commissioning that may be hidden in the higher (and ubiquitous) 3%/3 mm passing rates [33].

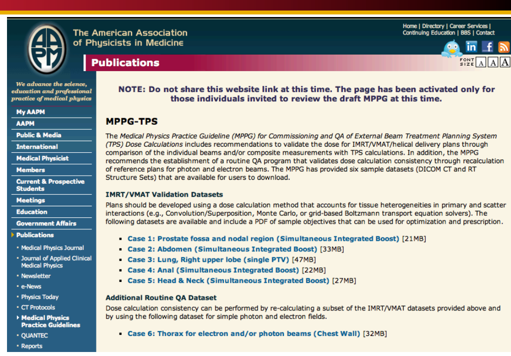
Implemention: TG 119 C-shaped plan on tomo with Delta4



- Delta4 2%2mm (global) gamma analysis
- Use only detectors with >20% signal
- Excellent results, 100% pass



Downloadable data sets with plan instruction



The American Association of Physicists in Medicine

Home | Directory | Career Services | Continuing Education | BBS | Contact

Publications

FONT SIZE A A A

We advance the science, education and professional practice of medical physics

- My AAPM
- AAPM
- Public & Media
- International
- Medical Physicist
- Members
- Current & Prospective Students
- Meetings
- Education
- Government Affairs
- Publications
  - Medical Physics Journal
  - Journal of Applied Clinical Medical Physics
  - Newsletter
  - e-News
  - Physics Today
  - CT Protocols
  - Medical Physics Practice Guidelines
  - QUANTEC
  - Reports

NOTE: Do not share this website link at this time. The page has been activated only for those individuals invited to review the draft MPPG at this time.

MPPG-TPS

The *Medical Physics Practice Guideline (MPPG) for Commissioning and QA of External Beam Treatment Planning System (TPS) Dose Calculations* includes recommendations to validate the dose for IMRT/VMAT/helical delivery plans through comparison of the individual beams and/or composite measurements with TPS calculations. In addition, the MPPG recommends the establishment of a routine QA program that validates dose calculation consistency through recalculation of reference plans for photon and electron beams. The MPPG has provided six sample datasets (DICOM CT and RT Structure Sets) that are available for users to download.

IMRT/VMAT Validation Datasets

Plans should be developed using a dose calculation method that accounts for tissue heterogeneities in primary and scatter interactions (e.g., Convolution/Superposition, Monte Carlo, or grid-based Boltzmann transport equation solvers). The following datasets are available and include a PDF of sample objectives that can be used for optimization and prescription.

- **Case 1: Prostate fossa and nodal region (Simultaneous Integrated Boost)** [21MB]
- **Case 2: Abdomen (Simultaneous Integrated Boost)** [33MB]
- **Case 3: Lung, Right upper lobe (single PTV)** [47MB]
- **Case 4: Anal (Simultaneous Integrated Boost)** [22MB]
- **Case 5: Head & Neck (Simultaneous Integrated Boost)** [27MB]

Additional Routine QA Dataset

Dose calculation consistency can be performed by re-calculating a subset of the IMRT/VMAT datasets provided above and by using the following dataset for simple photon and electron fields.

- **Case 6: Thorax for electron and/or photon beams (Chest Wall)** [32MB]

Section 8: Electron Beam Verification

Table 9: Basic TPS validation tests for electron beams and minimum tolerance values

Test	Objective	Description	Tolerance
8.1	Basic model verification with shaped fields	Custom cutouts at standard and extended SSDs	3%/3 mm
8.2	Surface irregularities-obliquity	Oblique incidence using reference cone and nominal clinical SSD	5%
8.3	Inhomogeneity test	Reference cone and nominal clinical SSD	7%

Section 9 QA

- Annually or after major TPS upgrades
- Reference plans should be selected at the time of commissioning and then re-calculated for routine QA comparison.
- For photons, representative plans for each configured beam should be chosen from Table 4 for static and wedge beams and Table 7 for IMRT/VMAT. Optionally, an additional thorax dataset with contours and suggested static beam parameters can be downloaded and used for some of these tests, (http://www.aapm.org/pubs/tg244/). A 10x10 cm^2 field and a small field (e.g. 5x5 cm^2) can be prescribed to the isocenter located in the center of the PTV. Wedged fields and dynamic arc plans can also be calculated on the thorax data set.
- For electrons, plans should be calculated for each energy using a heterogeneous dataset with reasonable surface curvature. The sample thorax dataset is also suitable for this test. Recommended plans also include extended distance and bolus verification.
- The routine QA re-calculation should agree with the reference dose calculation to within 1%/1mm. A complete re-commissioning (including validation) may be required if more significant deviations are observed.

Checklist to guide commissioning report

TG244 Section	TG244 Item	Commissioni Report Page
1	QMP understands algorithms and has received proper training.	
3	Manufacturer's guidance for data acquisition was consulted and followed.	
3.b	Appropriate CT calibration data acquired.	
3.d	Review of raw data (compare with published data, check for error, confirm import into TPS).	
4	Beam modeling process completed according to vendor's instructions.	
4	Beam models evaluated qualitatively and quantitatively using metrics within the modeling software.	
5	For each beam model perform validation tests 5.1-5.8 (5.9 for non-physical wedge) according to methods and tolerances in Tables 3 and 4.	
6	Heterogeneity corrections validated for photon beams according to Table 6.	
7	IMRT and VMAT validations accomplished for each configured beam according to tests 7.1-7.4 in Table 7.	
7	End-to-End test with external review accomplished for IMRT and VMAT (test 7.5 in Table 7).	
7	Understand and document limitations of IMRT/VMAT modeling and dose algorithms.	
8	Electron validations performed according to tests 8.1-8.3 in Table 9.	
9	Baseline QA plan(s) (for model constancy) identified for each configured beam and routine QA established.	
10	Peer review obtained and any recommendations addressed.	

Next steps….

- Respond to public comment reviewer comments
- Submit to JACMP – await final review
- Continue implementation of MPPG on Varian, TomoTherapy and Elekta (AAPM annual meeting abstract)
  - Fine tune gamma analysis in MatLab code, analyze remaining Trilogy and Infinity data
  - Take heterogeneous and electron data
  - Create test suite for each machine type (Pinnacle/Eclipse plans, R&V entry and scan Q's)
- Make gamma analysis code easily available (and easier data input)

Thanks to my collaborators, and to you for your attention!

- All MPPG#5 members!
- UW clinical physicists who helped with implementation
  - Adam Bayliss
  - John Bayouth
  - Ed Bender
  - Jessica Miller
- UW Medical Physics graduate students
  - Jeremy Bredtfeldt
  - Sam Simiele